PHOTOMASK

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The relationship between mounting pressure and time on final photomask flatness

Takashi Mizoguchi and Satoshi Akutagawa, Toppan Photomasks, Inc (USA), 1000 River Street, Mail Stop 9651A, Essex Junction, VT 05452, USA

Monica Barrett, Michael Caterer, Robert Nolan, Dennis Plouffe, and Nancy Zhou, IBM Corp. (USA), 1000 River Street, Mail Stop 9651A, Essex Junction, VT 05452, USA

ABSTRACT

Photomask flatness and image placement specifications for advanced technology masks are becoming more stringent. Therefore, it is important to understand the various factors that affect final photomask flatness due to the direct impact it has on image placement. Past studies have demonstrated that final photomask flatness can be controlled by modifying the mounting process of photomask pellicle as well as changing the pellicle material itself.[1,2,3,4] In particular, our previous results demonstrate the ability to successfully eliminate data deviations by remounting the same pellicle for each experiment. This paper focuses on the relationship between mounting pressure and time on final photomask flatness. Our initial results indicate that mounting time has minimal influence on final photomask flatness; however, final photomask flatness is greatly impacted by varying mounting pressure. Finally we explore the relationship between the final photomask flatness and the image placement for post pellicle mounting onto the photomask.

1. Introduction

There are two contributors to final photomask flatness: the pellicle material itself and the pellicle mounting process. The primary material contributors are frame flatness, adhesive shape, pellicle height, and adhesive material. Recent studies[5] have demonstrated that pellicle frame height also has a significant impact on the final flatness. The conclusion reported is that the better the

Continues on page 3.

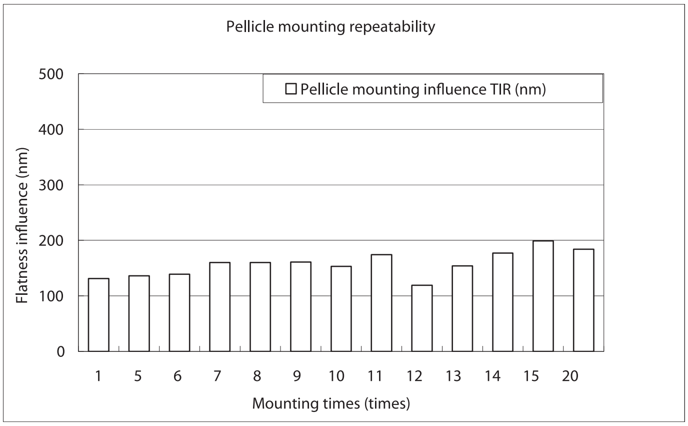

Figure 1. Flatness influence using a single pellicle repeated 20 times.

TAKE A LOOK INSIDE:

Editorial

From the Editor: Mask Inspection - Continued

We are continuing the discussion about EUV inspection tools started in the previous issue of the Newsletter.

Can EUV Lithography Adoption be Limited by the Lack of a Production Mask Inspector for <= 16 nm HP?

By **Gregg Inderhees,** KLA-Tencor

As EUV lithography continues to develop toward a planned insertion at the 16 nm HP node by 2015, mask inspection companies and the rest of the industry are struggling to identify and develop suitable technologies to support EUV mask production. SEMATECH, through the formation of the EUV Mask Infrastructure consortium (EMI) has been studying this issue for a year now. The consortium's consensus is that current 19x nm-based inspection technologies cannot meet the industry's production needs at 16 nm, thus a new technical approach is required.

Mask inspectors must meet multiple criteria for a production use-case:

- 100% defect capture with < 100 false defects
- short scan times (< 6 hrs) to support required cycle times
- no mask damage or added contamination during inspection
- support for single-die or non-uniform multi-die masks (ie. flare correction), and
- reasonable tool price to achieve economically viable cost-per-inspection targets.

Currently, there are two basic technologies that have been identified as candidates for 16 nm HP EUV production, an actinic (ie. at the scanner wavelength of 13.5 nm) and an e-beam based approach. An actinic-based system has several important advantages over an e-beam method to meet production use-case requirements: 1) inherently higher contrast and lower noise levels, which are critical to achieving the required capture rate vs. false count criteria, 2) a clear path to short scan times using EUV light sources already commercialized today, 3) extendibility to future nodes without an untenable throughput penalty, 4) lower risk of thermal damage to the fragile EUV blank multilayer mirror, and 5) ability to capture phase defects, which are a significant source of EUV mask defectivity. In addition, a KLA-Tencor actinic solution would have the advantage of access to more than 20 years of experience using production-proven die-to-database algorithms and modeling with high-resolution reticle plane inspection.

From an equipment supplier's point-of-view, the business model challenges to develop an actinic EUV mask inspector are extremely daunting. As is true in many other parts of the semiconductor supply chain, the mask inspection business model has seen an ever-increasing cost to develop new technologies, and a continually decreasing (through consolidation and shrinking unit volume) market opportunity. It is also true that while EUV lithography currently is the front-up solution for most semiconductor manufacturers for 16 nm HP production, there remains much risk in this scenario. For these reasons, the EMI consortium was formed to provide a structure to fund a Concept phase feasibility study to more precisely quantify the schedule, cost, technical risks, and requirements for a 16 nm EUV reticle inspector. Originally, EMI planned to issue a Request For Proposal and provide funding for a Concept phase by the end of CY 2009. Currently, the plan calls for funding (best case) at the end of 2010, a delay of one year. This difference is critical, because the timeline for EUV insertion is driven by Moore's Law, with leading semiconductor companies planning 16 nm HP production in 2015. Without near-term funding for a mask inspection Concept phase, the risk to achieve a production-capable EUV mask inspector by 2015 grows day-by-day with each slip. This delay puts at risk the widespread adoption of EUV lithography.

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Managing Editor/Graphics Linda DeLano
Advertising Al Ragan
BACUS Technical Group Manager Pat Wight

SPIE

P.O. Box 10, Bellingham, WA 98227-0010 USA
Tel: +1 360 676 3290 or +1 888 504 8171
Fax: +1 360 647 1445
SPIE.org
customerservice@spie.org

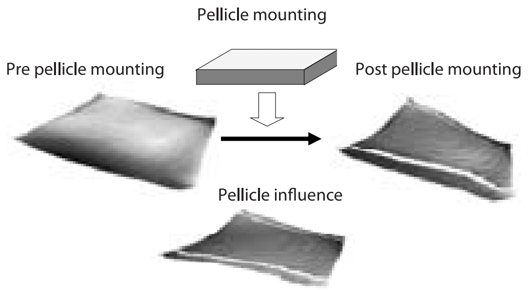

Figure 2. Flatness calculation for the pre- pellicle to post-pellicle mounting contribution.

shape of the pellicle adhesive, the better final flatness. This result is independent of the adhesive material.

The primary contributions from the mounting process are mask backing type, mounting direction, mounting pressure, and mounting time. A previous report[6] concluded that mask backing type and pellicle mounting direction do not strongly affect the final photomask flatness. In that experiment, we developed a method to reduce the errors while evaluating flatness. The method is to reuse the same pellicle for multiple flatness tests to eliminate the inherent frame flatness and pellicle flatness contributions. The consistency of this method is shown in Figure 1. The pellicle mounting process includes not only the mask backing material and mounting direction, but also mounting time and mounting pressure. This paper reports how the pellicle mounting time and pellicle mounting pressure affects final photomask flatness.

2. Experimental

2.1 Materials and mounting tool

The pellicles used in this study were obtained from several pellicle suppliers. The pellicles have outer dimensions 149 x 115mm and a 5mm frame height as shown in Table 1. The photomask blanks are typical Cr on glass substrates without e-beam resist. The blanks are selected to have an initial flatness of 0.5um or less in the 142 x 142mm measurement area.

Some of the experimental data were collected from patterned photomasks. Mounting pressure and time can be adjusted automatically. Typical acid cleans were used to remove the pellicle glue from the Cr surface between each pellicle mount.

Table 1 Pellicle description.

Pellicle type	Frame outer dimension	Pellicle height (mm)	Adhesive type
A	115x149	5	1
B	115x149	5	2
C	115x149	5	3

2.2 Flatness measurement and photomask flatness analysis

The initial and final flatness of blanks was 0.5um or less. The same blank was used for each experiment. All flatness measurements were performed on the chromium side of the blank using a nominal incidence interferometer photomask flatness measurement tool with He-Ne laser 633nm wavelength. The measurement area was 142 x 142mm and measurements included both the area inside and outside of the pellicle frame. Flatness analysis area can be performed on any area within the measurement area.

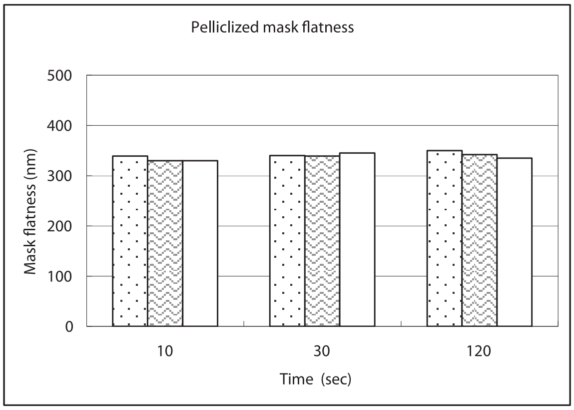

Figure 3. Final photomask flatness as a function of changing the pellicle mounting time at fixed mounting pressure.

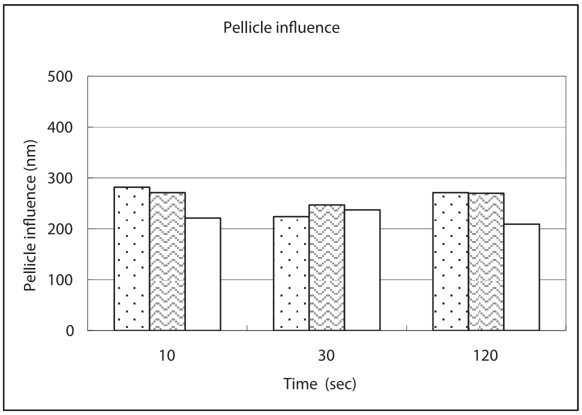

Figure 4. The pellicle flatness influence as a function of changing the pellicle mounting time at fixed mounting pressure.

For each mounting experiment the flatness of the photomask blank was initially measured without pellicle and then a pellicle was mounted onto the blank. Flatness was calculated using a Legendre polynomial fit resulting in a contour map and total indicated range (TIR) value. The difference between pre- and post-pellicle mounting flatness is calculated by point-to-point subtraction as shown Figure 2.

3. Result

3.1 Dependence of pellicle mounting time

Keeping the pellicle mounting pressure constant, the pellicle was mounted onto the blank with normal pressure. To reduce deviations introduced by different pellicle flatnesses, the same pellicle and blank were used in this experiment.

Figure 3 shows the data collected on a single pellicle mounted nine times. Even though pellicle mounting time was changed, the final flatness of the pelliclized mask remained unchanged. Figure 4 shows that the pellicle influence does not depend strongly on mounting time. To confirm this result, the experiment was repeated with pellicle A and the trend was repeated.

3.2 Dependence of pellicle mounting pressure

The second experiment evaluates how the pellicle mounting pressure affects final photomask flatness. In contrast to the previous experiment, the pellicle mounting time was fixed. The final photomask flatness and flatness influence was determined using the same method illustrated in Figure 2 with pellicle A. The results are shown in Figure 5 and indicate that the lower the mounting pressure, the better the final photomask flatness. When

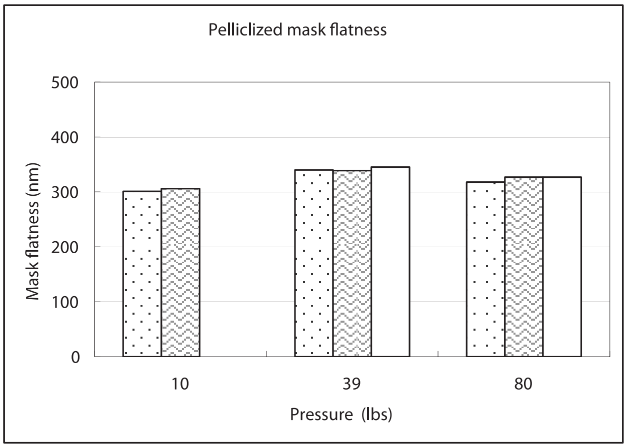

Figure 5. Final photomask flatness as a function of the pellicle mounting pressure at fixed mounting time.

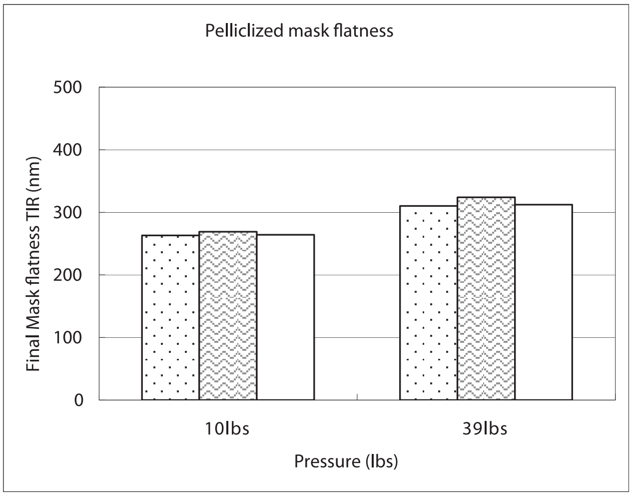

Figure 6. The final flatness for convex shaped blank mounted a pellicle.

the same experiment was repeated with pellicle B, the equivalent trend was found.

3.2.1 Dependence of initial flatness on map trends

The final photomask flatness is a result of both the initial flatness before pellicle mounting and the pellicle influence on the initial mask flatness. It is important to understand that not only reducing pellicle influence, but also matching initial flatness and pellicle flatness affects the interaction. To differentiate low final photomask flatness from matching to initial mask flatness, another blank was prepared. The mask had 0.5um flatness in 142 x 142mm area and a different shape from the blank above. The initial blank shape was concave, and the blank for this experiment was convex. The data in Figure 6 was obtained from convex blank and can be compared to the result in Figure 5. The results are very similar, regardless of the blank shape. The final photomask flatness is not strongly influenced by the initial mask's shape.

3.2.2 Dependence of adhesive and vendor (a pellicle made by another vendor)

There are many adhesive types available for photomask pellicles. The above results were obtained using an acrylic adhesive (pellicle A and pellicle B). Another composition is required to verify that the results hold for other adhesives.

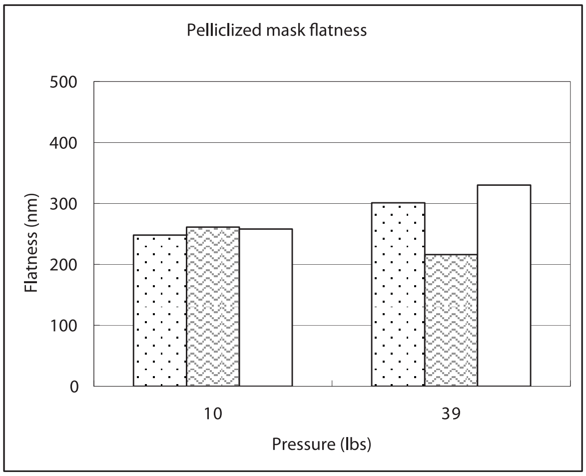

Figure 7. Final photomask flatness using a pellicle based on SEBS adhesive type.

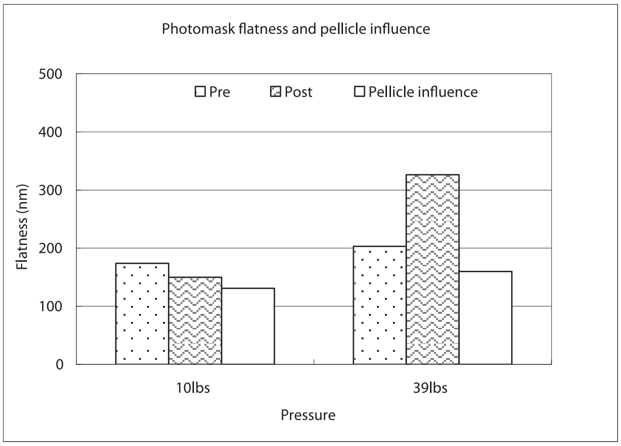

Figure 8. Photomask flatness and pellicle influence (measurement area: 132 x 80mm).

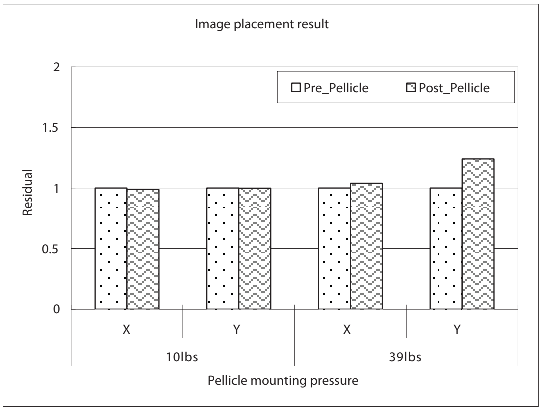

Figure 9. Image placement result (measurement area: 132 x 80mm).

Styrene ethylene butyl styrene (SEBS) was selected as the alternate pellicle adhesive material. Unfortunately, the SEBS adhesive can not be mounted multiple times because of the glue stickiness. Instead, a new pellicle is required for each pellicle mounting attempt. Figure 7 shows the data collected using SEBS adhesive

Table 2. Void level in glue as a function of mounting pressure.

	10lbs	39lbs
Pellicle A	Longer mounting time, there are tiny voids	No problem
Pellicle B	Many small voids at 0 hr; only 1 after 24 hours	3 small voids at 0 hrs; only 2 remain after 24 hrs
Pellicle C	Post 24 hour, almost all voids disappear	Post 24 hour, almost all voids disappear

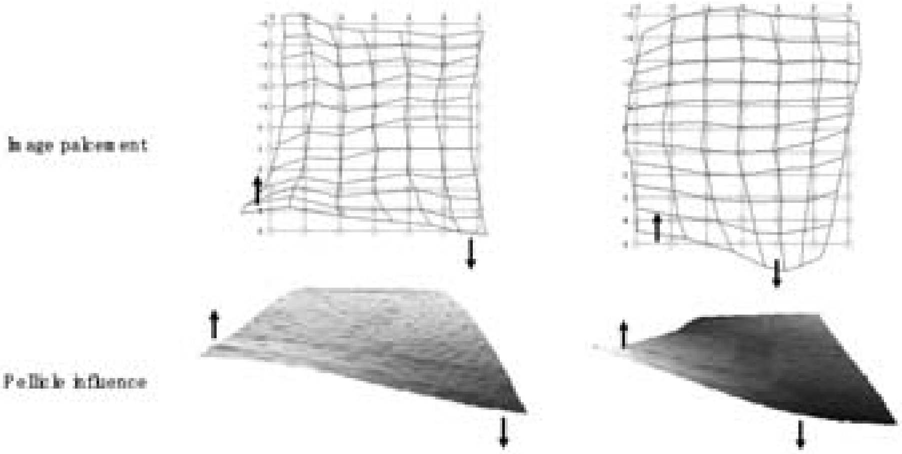

Figure 10. Pre- and post- pellicle subtraction maps of image placement map (top) and flatness influence map (bottom).

(pellicle C). According to this result, adhesive type does not affect final flatness. This implies that the pellicle adhesive does not affect the final photomask flatness. Instead, it is the pellicle mounting pressure that impacts the final photomask flatness.

3.3 Safety for lower pressure

It has been established that lower mounting pressures improve final photomask flatness, however there are several other dependencies. It is important to check whether lower pressure is sufficient to mount a pellicle securely to a photomask.

Voids in glue

Table 2 compares the voids in glue soon after mounting and 24 hours later for three samples. Two mounting pressures were applied and the results were obtained using an optical microscope. Immediately after pellicle mounting, there are several voids in glue. 24 hours later, the number of voids is reduced to reasonable levels.

Air blow test

This test was performed to complement the above void experiment. After the pellicle was mounted, air was blown at an angle towards the sealed area. If the adhesive had large voids, air would be able to get into it through the space inside the pellicle and the membrane would rupture. Using the air gun, air was directed close to the frame without hitting it. The membrane did not rupture demonstrating that the low pressure of 10lbs is sufficient to seal the pellicle region.

Vibrational test and centrality position of a mounted pellicle

The mask mounted with a pellicle using low pressure was vibrated in multiple directions for 30 minutes. All pellicles remained firmly mounted to the photomask. The position of the mounted pellicle was measured against the pellicle centrality specification. Multiple points were measured from the frame to mask edge before and after the vibrational test.

Even after strong vibrational testing, the mounted pellicle remained at essentially the same position.

3.4 The relation between image placement and flatness

We have confirmed that lower mounting pressure improves final photomask and that lower pressure can maintain the qualification at standard pressures. We also studied the relationship between photomask flatness and photomask image placement (IP). Two photomasks that had approximately the same flatness contour maps and TIR values were prepared.

Figure 8 shows the flatness result. The pellicle used was type C. The flatness measurement area (133 x 80mm) was chosen to be inside pellicle frame to enable matching to the image placement result. The final photomask flatness of the mask mounted with 10lbs is much better than with 39lbs. The pellicle influence at 10lbs mounting pressure is better than that of 39lbs. Low mounting pressure not only improves the final photomask flatness, but also improves the pellicle influence.

The image placement of a photomask was measured both pre- and post-pellicle mounting. Figure 9 shows the associated image placement results. The data for pre-pellicle image placement was normalized to 1. At low pressures the change in image placement between pre- and-post mounting is very small. In contrast, high mounting pressure degrades the image placement. The y data is affected the most because this is the long axis of the pellicle frame and interacts with the mask over a longer spatial extent. Figure 8 and Figure 9 show that the photomask flatness is correlated to the image placement of a photomask. Flatter photomasks have lower image placement errors.

The subtraction map of image placement shows a tendency similar to the flatness influence. Figure 10 shows the subtraction contour maps for both the 10lbs and 39lbs mounting pressure. The 10lbs result is shown on the left and the 39lbs result is shown on the right side of Figure 10. Both measurement areas were set to 132 x 80mm. Regardless of mounting pressure, the tendency of the image placement contour map between pre and post pellicle mounting is very similar to the tendency of flatness influence contour map.

4. Summary and conclusion

It has been shown that lower pellicle mounting pressures improve the final photomask flatness. Even at the lower mounting pressures, the mount quality of final the photomask is as good as the mount quality achieved at higher pressures. This assertion was confirmed using air pressure and vibrational testing. The pellicle mounting time does not strongly affect final photomask flatness either. The dependence of this result on adhesive material was verified using two adhesive types: SEBS and acrylic. In both cases, the final photomask flatness remained consistent. This result suggests that the pellicle adhesive had little effect on the final photomask flatness.

The flatness contour shape of the initial photomask, i.e. convex or concave, does not strongly affect the final photomask flatness. Regardless of the initial photomask flatness shape, lower mounting pressure improves the final photomask flatness.

Finally, we studied the relationship between photomask flatness and photomask image placement. Lower mounting pressure not only improved the final photomask flatness, but also improved the image placement post pellicle mount.

The flatness influence across-mask is correlated to the pre minus post-pellicle mount subtraction map of image placement. This result indicates that it is not only important to check the flatness performance for post-pellicle. This post-pellicle mount flatness data is especially important if post-pellicle image placement metrology is not performed.

5. References

[1] E. Cotte, R. Engelstad, E. Lovell, D. Tanzil, F. Eschbach, Y. Korobko, M. Fujita, and H. Nakagawa, “Effects of Soft Pellicle Frame Curvature and Mounting Process On Pellicle-Induced Distortions in Advanced Photomasks”, SPIE, Vol 5040, pp. 1044-1054, 2003.

[2] C. Lee, K. Racette, and M. Barrett, “Investigation of Pellicle Influence on Reticle Flatness”, SPIE, Vol 5853, pp. 516-524, 2005.

[3] R. Wistrom, D. Hayden, K. Racette, M. Barrett, and A. Watts, “Influence of Pellicle on Final Photomask Flatness”, **Proc. SPIE 6283-39**, 2006.

[4] K. Racette, A. Watts, M. Barrett, R. Nolan, Y. Sasaki, Y. Kikuchi, and T. Matsumura, “Pellicle Factors Affecting Finished Photomask Flatness”, **Proc SPIE, Vol 6607**, 2007.

[5] N. Zhou, K. Racette, M. Hibbs, T. Mizougchi, D. Hasselbeck, M. Barrett, R. Nolan, F. Houle, J. Ritter, A. Wagner, and M. Caterer, “Evaluation of 32nm Advanced Immersion Lithography Pellicles”, **Proc. SPIE 7122**, 71220B(2008).

[6] T. Mizoguchi, S. Akutagawa, M. Barrett, M. Caterer, R. Nolan, K. Racette, D. Plouffe, and N. C. Zhou, “Evaluation of the Flatness Eeffects of Mask Backing and Orientation During Photomask Pellicle Mount”, **Proc. SPIE 7379**, 2009.

Industry Briefs

Sematech Partners with Dai Nippon Printing, Ltd (DNP)

SEMATECH global consortium of the world's leading chip manufacturers, entered a partnership with Dai Nippon Printing, Ltd (DNP) a provider, to accelerate commercialization of advanced mask lithography technology, such as EUV, non-patterned, and nanoimprint lithography. SEMATECH and Dai Nippon will collaborate at the College of Nanoscale Science and Engineering (CNSE) of the University at Albany on methods for improving mask cleaning processes to reduce overall mask cost of ownership (COO) and accelerate commercial manufacturing readiness in wafer fab.

A method was presented three years ago for controlling ammonium sulfate haze by maintaining 193nm reticles in a low humidity environment. Since then, this approach has became an industry standard and is widely used in production fabs around the world. Based on analysis of practical applications in HVM fabs, Entegris describes a successful approach to reticle haze control outlines its critical elements and explains its limiting factors.

Maskless Lithography

SPIE Photomask Symposium (September 13-17) in Monterey, CA will feature a special session on “Maskless Lithography”. The focus of the session is to provide the photomask industry with an insight with respect to how this technology will compliment the mask industry, rather than compete against it. All key areas of maskless lithography will be addressed from design data management to resist and process challenges. With the continued delays in the implementation of EUV, maskless lithography is gaining recognition amongst the wafer lithography community. The all-day special session will be held on Wednesday, September 15.

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About the BACUS Group

Founded in 1980 by a group of chrome blank users wanting a single voice to interact with suppliers, BACUS has grown to become the largest and most widely known forum for the exchange of technical information of interest to photomask and reticle makers. BACUS joined SPIE in January of 1991 to expand the exchange of information with mask makers around the world.

The group sponsors an informative monthly meeting and newsletter, BACUS News. The BACUS annual Photomask Technology Symposium covers photomask technology, photomask processes, lithography, materials and resists, phase shift masks, inspection and repair, metrology, and quality and manufacturing management.

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Calendar

2010

SPIE Photomask Technology

13-16 September
Monterey Marriott and
Monterey Conference Center
Monterey, California, USA
spie.org/pm

Late submissions will be considered by Chairs.

2011

SPIE Advanced Lithography

27 February-4 March
San Jose Marriott and
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Extended Abstract Due Date: 8 September 2010.

You are invited to submit events of interest for this calendar. Please send to lindad@spie.org; alternatively, email or fax to SPIE.

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Tel: +1 888 504 8171 or +1 360 676 3290
Fax: +1 360 647 1445
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